THE SCIENTIFIC ORDERS OF THE "CHALLENGER"

I.

WE have received from the Admiralty permission to publish the following Report of the Circumnavigation Committee of the Royal Society, on the work which lies before the *Challenger* Expedition. We are sure its perusal will gratify all our readers.

The principal object of the proposed expedition is understood to be to investigate the physical and biological conditions of the great ocean-basins; and it is recommended for that purpose to pass down the coast of Portugal and Spain, to cross the Atlantic from Madeira to the West Indian Islands, to go to Bermuda, thence to the Azores, the Cape de Verde Islands, the coast of South America, and across the South Atlantic to the Cape of Good Hope. Thence by the Marion Islands, the Crozets, and Kerguelen Land, to Australia and New Zealand, going southwards *en route*, opposite the centre of the Indian Ocean, as near as may be with convenience and safety to the southern ice-barrier. From New Zealand through the Coral Sea and Torres Straits, westward between Lombok and Bali, and thence through the Celebes and Sulu Seas to Manilla, then eastward into the Pacific, visiting New Guinea, New Britain, the Solomon Islands; and afterwards to Japan, where some considerable time might be profitably spent. From Japan the course should be directed across the Pacific to Vancouver Island, then southerly through the eastern trough of the Pacific, and homewards round Cape Horn. This route will give an opportunity of examining many of the principal ocean phenomena, including the Gulf-stream and equatorial currents; some of the biological conditions of the sea of the Antilles; the fauna of the deep water of the South Atlantic, which is as yet unknown, and the specially interesting fauna of the borders of the Antarctic Sea. Special attention should be paid to the botany and zoology of the Marion Islands, the Crozets, Kerguelen Land, and any new groups of islands which may possibly be met with in the region to the south-east of the Cape of Good Hope. Probably investigations in these latitudes may be difficult; it must be remembered, however, that the marine fauna of these regions is nearly unknown, that it must bear a most interesting relation to the fauna of high northern latitudes, that the region is inaccessible except under such circumstances as the present, and that every addition to our knowledge of it will be of value. For the same reasons the expedition should, if possible, touch at the Auckland, Campbell, and especially the Macquarie Islands. Particular attention should be paid to the zoology of the sea between New Zealand, Sydney, New Caledonia, and the Fiji and Friendly Islands, as it is probable that the Antarctic fauna may be found there at accessible depths. New Britain and New Ireland are almost unknown, and from their geographical position a special interest attaches to their zoology, botany, and ethnology. The route through this part of the Pacific will give an opportunity of checking and repeating previous observations on the structure of coral reefs and the growth of coral, and of collecting series of volcanic rocks. The Japan current will also be studied, and the current along the coast of California. The course from Japan to Vancouver Island and thence to Valparaiso will afford an opportunity of determining the physical geography and the distribution of life in these regions, of which at present nothing is known.

I.—*Physical Observations*

In crossing the great ocean basins observations should be made at stations the positions of which are carefully determined, chosen so far as possible at equal distances, the length of the intervals being of course dependent on circumstances. At each station should be noted the time of the different observations, the state of the weather, the temperature of the surface of the sea, the depth, the bottom temperature determined by the mean of two Miller-Casella thermometers, the specific gravity of the surface- and bottom-waters. The nature of the bottom should be determined by the use of a sounding-instrument constructed to bring up samples of the bottom, and also, if possible, by a haul of the dredge. When practicable, the amount and nature of the gases contained in the water, and the amount and nature of the salts and organic matter should be ascertained. As frequently as possible, especially in the path of currents, serial temperature-soundings ought to be taken either with the instrument of Mr. Siemens, or with the Miller-Casella thermometer, and in the latter case at intervals of 10, 50, or 100 fathoms, to determine the depth and volume of masses of moving water derived from different sources.

The simple determination of the depth of the ocean at tolerably regular distances throughout the entire voyage is an object of such primary importance that it should be carried out whenever possible, even when circumstances may not admit of dredging, or of anything beyond sounding. The investigation of various problems relating to the past history of the globe, its geography at different geological epochs, and the existing distribution of animals and plants, as well as the nature and causes of oceanic circulation, will be greatly aided by a more accurate knowledge of the contour of the ocean-bed.

Surface-Temperature.—The surface-temperature of the sea, as also the temperature of the air as determined by the dry- and wet-bulb thermometers, should be regularly recorded every two hours during the day and night throughout the voyage.

These records should be reduced to curves for the purpose of ready comparison; and the following points should be carefully attended to:—

1. In case of a general correspondence between the temperature of the sea and that of the air, it should be noted whether in the diurnal variation of both, the sea appears to *follow* the air, or the air the sea.

2. In case of a marked discordance, the condition or conditions of that discordance should be sought in (*a*) the direction and force of the wind, (*b*) the direction and rate of movement of the ocean surface-water, (*c*) the hygrometric state of the atmosphere. When the air is very dry, there is reason to believe that the temperature of the surface of the sea is reduced by excessive evaporation, and that it may be below that of the subsurface stratum a few fathoms deep. It will be desirable, therefore, that every opportunity should be taken of comparing the temperature at the surface with the temperature of the subsurface stratum—say at every 5 fathoms down to 20 fathoms.

Temperature-Soundings.—The determination of the temperature, not merely of the bottom of the ocean over a wide geographical range, but of its various intermediate strata, is one of the most important objects of the expedition; and should, therefore, be systematically prosecuted on a method which should secure comparable results. The following suggestions, based on the experience already obtained in the North Atlantic, are made for the sake of indicating the manner in which time and labour may be economised in making serial soundings, in case of the employment of the Miller-Casella thermometer. They will be specially applicable to the area in which the work of the expedition will commence; but the thermal conditions of other areas may prove so different, that the method may need considerable modification.

The following strata appear to be definitely distinguishable in the North Atlantic:—(*a*), a "superficial stratum," of which the temperature varies with that of the atmosphere, and with the amount of Insolation it receives. The thickness of this stratum does not seem to be generally much above 100 fathoms, and the greatest amount of heating shows itself in the uppermost 50 fathoms. (*b*) Beneath this is an "upper stratum," the temperature of which slowly diminishes as the depth increases down to several hundred fathoms; the temperature of this stratum, in high latitudes, is considerably *above* the normal of the latitude; but in the inter-tropical region it seems to be considerably *below* the normal. (*c*) Below this is a stratum in which the rate of diminution of temperature with increasing depth is rapid, often amounting to 10° or more in 200 fathoms. (*d*) The whole of the deeper part of the North Atlantic, below 1,000 fathoms, is believed to be occupied by water not many degrees above 32°. With regard to this "glacial stratum," it is exceedingly important that its depth and temperature should be carefully determined.

It will probably be found sufficient in the first instance to take, with each deep *bottom* sounding, *serial* soundings at every 250 fathoms, down to 1,250 fathoms; and then to fill up the intervals in as much detail as may seem desirable. Thus where the fall is very small between one 250 and the next, or between any one and the bottom, no intermediate observation will be needed; but where an abrupt difference of several degrees shows itself, it should be ascertained by intermediate observations whether this difference is sudden or gradual.

The instrument devised by Mr. Siemens for the determination of submarine temperatures is peculiarly adapted for serial measurements, as it does not require to be hauled up for each reading. It should, however, be used in conjunction with the Miller-Casella thermometer, so as to ascertain how far the two instruments are comparable; and this point having been settled, Mr. Siemens's instrument should be used in all serial soundings; and frequent readings should be taken with it, both in descending and ascending.

A question raised by the observations of the U.S. Coast Surveyors in the Florida Channel, and by those of our own surveyors in the China Sea, is the extent to which the colder and therefore heavier water may run *up hill* on the sides of declivities. The position of the Azores will probably be found very suitable for observations of this kind. Temperature-soundings should be taken at various depths, especially on their north and south slopes, and in the channels between the Islands; and the temperatures at various depths should be compared with those of corresponding depths in the open ocean.

It is in the southern oceans that the study of ocean-temperatures at different depths is expected to afford the most important results; and it should there be systematically prosecuted. The great ice-barrier should be approached as nearly as may be deemed suitable, in a meridian nearly corresponding to the centre of one of the three great southern oceans;—say to the south of Kerguelen's Land; and a line of soundings should be carried north and south as nearly as may be.

In connection with the limitation of the area and depth of the reef-building corals, it will be very important to ascertain the rate of reduction of temperature from the surface downwards in the region of their greatest activity; as it has been suggested that the limitation of living reef-builders to 20 fathoms may be a thermal one.

Wherever any anomaly of temperature presents itself, the condition of such anomaly should, if possible, be ascertained. Thus there is reason to believe that the cause of the temperature of the surface-water being below that of the sub-surface stratum, in the neighbourhood of melting ice, is that the water cooled by the ice, by admixture with the water derived from its liquefaction, is also rendered less salt, and therefore floats upon the warmer and salter water beneath. Here the determination of Specific Gravities will afford the clue. In other instances a warm *current* may be found beneath a colder stratum; and the use of the "current-drag" might show its direction and rate. In other cases, again, it may happen that a warm submarine spring is discharging itself,—as is known to occur near the island of Ascension. In such a case, it would be desirable to trace it as nearly as may be to its source, and to ascertain its composition.

Movements of the Ocean.—The determination of *Surface*-Currents will, of course, be a part of the regular routine, but it is particularly desirable that accurate observations should be made along the line of sounding in the Southern Ocean, as to the existence of what has been described as a general "Southerly set" of Oceanic water, the rate of which is probably very slow. It is also very important that endeavours should be made to test by the "current-drag," whether any *underflow* can be shown to exist from either Polar basin towards the Equatorial region. A suitable locality for such experiments in the North Atlantic would probably be the neighbourhood of the Azores, which are in the line of the glacial flow from the North Polar Channel. The guide to the depth at which the current-drag should be suspended, will be furnished by the thermometer, especially where there is any abrupt transition between one stratum and another. It would be desirable that not only the rate and direction of surface-drift, but those of the subsurface-stratum at (say) 200 fathoms' depth, should be determined at the same time with those of the deep stratum.

Tidal Observations.—No opportunity of making tidal observations should be lost. Careful observations made by aid of a properly placed tide-pole in any part of the world will be valuable. Accurate measurements of the sea-level once every hour (best every *lunar* hour, *i.e.* at intervals of $1^h\ 2^m$ of solar time) for a lunar fortnight (the time of course being kept) would be very valuable information.

Bench-marks.—In reference to the interesting question of the elevation or subsidence of land, it will be very desirable, when sufficient tidal observations can be obtained to settle the mean level of the sea, that permanent bench-marks should be established, recording the date and height above such mean level. Even recording the height to which the tide rose on a certain day and time, would render a comparison possible in future years.

A good determination of the mean sea-level by the simple operation of taking means may be made, in less than two days, with even a moderate number of observations *properly distributed so as to subdivide both solar and lunar days into not less than three equal parts.* Suppose, for example, we choose 8-hour intervals, both solar and lunar. Take a lunar day at $24^h\ 48^m$ solar time, which is near enough, and is convenient for division; and choosing any convenient hour for commencement, let the height of the water be observed at the following times, reckoned from the commencement:—

h m.	h. m.	h m.
0 0	8 0	16 0
8 16	16 16	24 16
16 32	24 32	32 32

The observations may be regarded as forming three groups of three each, the members of each group being separated by 8 hours solar or lunar, while one group is separated from the next by 8 hours lunar or solar. In the mean of the nine results the lunar and solar semi-diurnal and diurnal inequalities are all four eliminated.

Nine is the smallest number of observations which can form a complete series. If the solar day be divided into m and the lunar into n equal parts, where m and n must both be greater than 2, there will be mn observations in the series; and if either m or n be a multiple of 3, or of a larger number, the whole series may be divided into two or more series having no observation in common, and each complete in itself. The accuracy of the method can thus be tested, by comparing the means obtained from the separate sub-series of which the whole is made up.

Should the ship's stay not permit of the employment of the above method, a very fair determination may be made in less than a day, by taking the mean of n observations taken at intervals of the nth part of a lunar day, n being greater than 2. Thus if $n=3$, these observations require a total interval of time amounting to only $16^h\ 32^m$. The theoretical error of this method is very small, and the result thus obtained is decidedly to be preferred to the mere mean of the heights at high and low water.

The mean level thus determined is subject to meteorological influences, and it would be desirable, should there be an opportunity, to redetermine it at the same place at a different time of year. Should a regular series of observations for a fortnight be instituted, it would be superfluous to make an independent determination of the mean sea-level by either of the above methods at the same time.

Besides taking observations on the ordinary waves of the sea when at all remarkable, the scientific staff should carefully note circumstances of any waves attributable to earthquakes.

Specific Gravity.—The Specific Gravity of the surface and bottom-water should be carefully compared, whenever soundings are taken; and whenever Serial Soundings are taken, the Specific Gravity at intermediate depths should be ascertained. Every determination of specific gravity should be made with careful attention to temperature; and the requisite correction should be applied from the best Table for its reduction to the uniform standard of 60°. It would be well to check the most important results by the balance; samples being preserved for examination in harbour. Wherever the temperature of the surface is high—especially, of course, in the intertropical region—samples should be collected at every 10 fathoms for the purpose of ascertaining whether any effect is produced upon the specific gravity of the upper stratum by evaporation, and how far down this effect extends.

Transparency of the Water.—Observations for transparency should be taken at various depths and under different conditions by means of Mr. Siemens's photographic apparatus. As, however, the action of this depends upon the more refrangible rays, and the absorption of these and of the more luminous rays might be different, and that in a manner varying with circumstances, such as the presence or absence of suspended matter, &c., the transparency of the sea should also be tested by lowering a white plate or large white tile to various measured depths, and noting the change of intensity and colour as it descends, and the depth at which it ceases to be visible. The state of the sky at the time should be mentioned, and the altitude of the sun, if shining, roughly measured, or if not shining, deduced from the time of day.

Relation of Barometric Pressure to Latitude.—In Poggendorff's "Annalen," vol. xxvi. 1832, p. 395, is a remarkable paper by Prof. G. F. Schouw on the relation between the height of the barometer at the level of sea, and the latitude of the place of observation. At page 434 is a rough statement of the results of his researches, the heights being given in Paris lines.

Lat. °	Barometer mercury at 0° C.
0	337·0
10	337·5
20	338·5
30	339·0
40	338·0
50	337·0
60	335·5
65	333·0
70	334·0
75	335·5

The expedition might contribute to the examination of this law, not only by giving special attention to the barometer observations at about the critical latitudes 0°, 30°, 65°, 70°, but also by comparing any barometers with which long series of observations have been made at any port they may touch at, with the ship's standard barometer.

It appears probable from Schouw's paper, that certain meridians are meridians of high pressure and others of low pressure.

For comparison of barometer and measures of heights, it appears that the aneroid barometer constructed by Goldschmid of Zurich, would be very useful.

It is very desirable that the state of the barometer and thermometer should be read at least every two hours.

(To be continued.)

TERRESTRIAL MAGNETISM*

II.

THE problem was attacked later on by General Sabine in a much more definite manner, and with much greater chance of success. The earth, as we are all well aware, moves round the sun in an elliptic orbit, the nearest approach of the two bodies occurring at about the time of the winter solstice; if, therefore, there be an annual inequality, it will probably attain its maximum when the earth is in perihelion, and its minimum at aphelion, since the magnetic force is known to vary inversely as the square of the distance. The year was, therefore, divided by Sabine into two equal parts, and the mean of all the observations taken during the six winter months compared with the mean for the six summer months. The records of the three British observatories of Hobarton, Toronto, and Kew all agree in showing that the magnetic intensity of the earth is greater in winter than in summer. This was very satisfactory; but the same calculations have since been made for other magnetic stations, where monthly determinations of the three elements are carried on without interruption, and some of the results are far from confirming the above conclusion; for we find that observatories as near as Kew and Greenwich are in direct opposition on this point. A more extensive series of comparisons will finally show how far this disagreement depends on the accidental nature of the observing stations; but at present the preponderance of the evidence is decidedly in favour of a semi-annual inequality.

A similar investigation of the effect of the moon's action on terrestrial magnetism requires a series of observations made at much less distant intervals than the monthly ones, which suffice for the study of the annual variation. This new question presents itself to our view under a twofold aspect. The effect of the moon may be studied either in its independent action, or as it acts conjointly with the sun; in the former case we must group the observations with respect merely to the position of the moon in its orbit, and, as this is an ellipse with the earth in the focus, the force, varying inversely as the square of the distance, will have its maximum disturbing influence at perigee and its minimum at apogee. The range also of the inequality will depend on the eccentricity of the orbit, and the period of variation will coincide with the siderial, or more strictly the anomalistic, month of a little over twenty-seven days.

But if we consider the moon as acted upon by the sun, receiving its magnetic power, as it does its light and heat, from the central body of our system, or merely having its own inherent magnetism modified by solar action, then we must choose as our unit the lunation, or synodic month of 29·5 days, observing the changes that take place as the moon approaches to or recedes from the sun. A careful sifting of the Greenwich observations led Mr. Airy to a belief in the existence of a menstrual inequality of the declination, attaining its maximum on the fifth day of the moon's age, and of a semi-menstrual inequality of the horizontal force whose maximum occurs on the second day. The solar effect on the moon's magnetic power would, therefore, appear to be cumulative, and not to be fully developed till several days subsequent to the conjunction of the two bodies.

No examination seems to have been as yet made to test the existence of a monthly variation due to the independent action of the moon, as the sole disturbing force.

The sun's rotation on his axis presents another not improbable cause of periodic magnetic disturbance. For if the sun acts as a large magnet directly upon the earth, and the poles of the sun's axis of rotation are not coincident with its magnetic poles, the rotation will present the solar magnetic poles alternately to the earth, and these acting singly, the result must be a synodic inequality, dependent on the period of the sun's rotation. The absence of any such irregularity is adduced, by a recent author on terrestrial magnetism, as a proof that the variations of the earth's magnetic force are due solely to the indirect action of the sun; but Prof. Hornstein has just succeeded in detecting in the magnetic records of Prague and Vienna an inequality in very close accord with the synodic period of the rotation of the solar spots. The magnetic period of 26 days 8 hours would give, as the true time of the sun's rotation, 24d. 13h. 12m., whereas Spörer, from the most accurate observations of spots near the sun's equator, found the time to be 24d. 12h. 59m. It becomes, therefore, probable that the sun has a direct magnetic action upon the earth, but this need not in the least interfere with the probability of its simultaneous indirect action by means of its thermal energy.

Having been able to detect, in the manner just described, the inequalities arising from the orbital motions of the earth and moon, we are immediately tempted to suppose that the diurnal rotation of the earth must also exert a not inconsiderable effect on the magnetism of any particular station on the earth's surface, and possibly even affect terrestrial magnetism as a whole. It is well known that change of temperature has a very powerful influence on magnetism, and therefore we should be astonished to find that the daily range of temperature induced no corresponding range in the earth's magnetic elements. The freely-suspended magnet is the most delicate of thermometers, and consequently, unless we wish the diurnal variation of the earth's magnetism to be completely veiled by the more extensive changes due to the varying heat of the magnet itself, we must take the greatest care to keep the suspended needle in a locality not directly affected by the daily alternations of temperature. Attending to this precaution, by building our magnetic chamber at a considerable depth below the surface of the ground, we still find that there exists a most decided daily range in the motion of the magnet, to which the most delicate thermometer is wholly insensible. This daily range was detected by Graham as early as 1724, and a momentary inspection of nearly any two days' march of the suspended needle will suffice to make this point evident. The maximum west declination, about 2 P.M., is constant throughout the year, whilst the principal minimum varies with the seasons, as do also the secondary maximum and minimum. Canton has accounted for the leading feature in this diurnal change by the fact that the solar heat lessens the magnetic power of that portion of the earth on which it directly falls, and thereby gives a preponderating influence to the opposite portion, whose strength remains undiminished; the needle, therefore, moves towards the West in the morning, and only returns towards the East as the Western sun restores the balance of attracting forces.

But there are other variations of the daily range besides those just mentioned, for not only do most of the inflections of the diurnal curves alter their time with the progress of the sun in his orbit, but the amplitude of the range passes through a constant order of phases as each year advances. Dr. Lloyd discovered that the maximum range of declination in summer is greater than in winter, and Quetelet not only confirms this, but also finds that the range is greater at the equinoxes than at the solstices. It was whilst engaged upon this investigation that the Director of the Brussels Observatory made the curious discovery, that the magnetic energy varies in the same manner as the vegetable force, both attaining their maximum in April, and diminishing gradually until they reach their minimum of intensity in the

* Continued from p. 173.